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JC927 U.S. PTO 09/82/60

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PTO/SB/05 (12/97)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	K35A0653
Total Pages	
First Named Inventor or Application Identifier	ANDREW D. HOSPODOR
Express Mail Label No.	EK995292717US

JC982 U.S. PTO 09/678177 09/28/00

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231**

1. [✔] Fee Transmittal Form *(Submit an original, and a duplicate for fee processing)*
2. [✔] Specification [*Total Pages* 23] *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [✔] Drawing(s) *(35 USC 113)* [*Total Sheets* 7]
   _X__ Formal __ Informal
4. Oath or Declaration [*Total Pages* 3]
   a. [✔] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 17 completed)* ***[Note Box 5 below]***
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. [ ] Incorporation By Reference *(useable if Box 4b is checked)* The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [ ] Microfiche Computer Program *(Appendix)*
7. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [ ] Assignment Papers (cover sheet & document(s))
9. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
10. [ ] English Translation Document *(if applicable)*
11. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
12. [ ] Preliminary Amendment
13. [✔] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
14. [ ] Small Entity Statement(s) [ ] Statement filed in prior application, Status still proper and desired
15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [✔] Other: BIBLIOGRAPHIC DATA FORM

17. **If a CONTINUING APPLICATION,** *check appropriate box and supply the requisite information:*
    [ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: _____/_____

18. CORRESPONDENCE ADDRESS

[ ] *Customer Number or Bar Code Label* *(Insert Customer No. or Attach bar code label here)* *or* [✔] *Correspondence address below*

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FEE TRANSMITTAL

Note: Effective October 1, 1997.
Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT ($) 1260.00

Complete if Known	
Application Number	UNKNOWN
Filing Date	HEREWITH
First Named Inventor	ANDREW D. HOSPODOR
Group Art Unit	UNKNOWN
Examiner Name	UNKNOWN
Attorney Docket Number	K35A0653

METHOD OF PAYMENT (check one)

1. [x] The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number: 23-1209
Deposit Account Name: WESTERN DIGITAL CORPORATION

[x] Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17
[ ] Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance

2. [ ] Payment Enclosed:
[ ] Check [ ] Money Order [ ] Other

FEE CALCULATION

1. FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	690.00
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	690	208	345	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 690.00

2. CLAIMS

			Extra		Fee from below		Fee Paid
Total Claims	43	-20 =	23	X	18	=	414.00
Independent Claims	5	- 3 =	2	X	78	=	156.00
Multiple Dependent Claims				X		=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim
109	78	209	39	Reissue independent claims over original patent
110	18	210	9	Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 570.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	380	216	190	Extension for reply within second month	
117	870	217	435	Extension for reply within third month	
118	1,360	218	680	Extension for reply within fourth month	
128	1,850	228	925	Extension for reply within fifth month	
119	300	219	150	Notice of Appeal	
120	300	220	150	Filing a brief in support of an appeal	
121	260	221	130	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,210	241	660	Petition to revive - unintentional	
142	1,210	242	605	Utility issue fee (or reissue)	
143	430	243	215	Design issue fee	
144	580	244	290	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	690	246	345	Filing a submission after final rejection (37 CFR 1.129(a))	
149	690	249	345	For each additional invention to be examined (37 CFR 1.129(b))	

Other fee (specify) ______________________

Other fee (specify) ______________________

* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($)

SUBMITTED BY				Complete (if applicable)	
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Signature	[signature]	Date	9/28/00	Deposit Account User ID	

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Application Information

Title Line One ::	Resource Reservation System In A Computer Network
Title Line Two::	To Support End-To-End Quality-Of-Service Constraints
Total Drawing Sheets ::	7
Formal Drawings ::	Yes
Application Type ::	Utility
Docket Number ::	K35A0653
Licensed - U S Government Agency ::	N/A
Contract Number ::	N/A
Grant Number ::	N/A
Secrecy Order in Parent Application ::	N/A

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RESOURCE RESERVATION SYSTEM IN A COMPUTER NETWORK TO SUPPORT END-TO-END QUALITY-OF-SERVICE CONSTRAINTS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to computer networks. More particularly, the present invention relates to a resource reservation system in a computer network to support end-to-end Quality-of-Service constraints.

Description of the Prior Art

Quality-of-Service (QOS) typically refers to a predetermined minimum latency and minimum data transfer rate supported by a computer network. Point-to-Point QOS is typically implemented within prior art networks by reserving resources through a path from the source node to the destination node (see the Resource Reservation Protocol or RSVP an overview for which is provided in the text book *Managing Bandwidth - Deploying QOS in Enterprise Networks*, by Alistair Croll and Eric Packman, Prentice Hall, Upper Saddle River, NJ, 1999; and "Resource Reservation Protocol (RSVP) -- Version 1 Functional Specification", Braden, R., Zhang, L., Berson, S., Herzog, S., Jamin, S., RFC 2205, September 1997, Proposed Standard). Reserving resources throughout the transmission path guarantees that the connection will support a desired QOS for a specified period. Implementing QOS constraints requires knowledge of the resources in each node and the connection between the nodes in the network including the transmission latencies and bandwidth.

Consider, for example, the prior art computer network 2 shown in FIG. 1. When client computer 4B attempts to access a data stream stored on a disk drive 6 attached to network server 8, a transmission path 10 through nodes 16a and 16b may be established by reserving the necessary resources at each node to support predetermined QOS constraints such as latency and data rate. During the life of the reserved transmission path 10, nodes 16a and 16b may be

inaccessible by other client computers (e.g., client computer 4C) if either node lacks the resources to handle additional traffic.

Because the mechanical latency of the disk drive 6 is not taken into account in the QOS equation, the network server 8 will typically buffer a sufficient amount of the data stream so that the mechanical latency of the disk drive 6 does not impact the QOS constraints. However, this implementation may require a significant amount of buffer memory and processing power at the network server 8 in order to support multiple, simultaneous streams. Further, for certain business transactions, such as bidding on auctions over a network, the QOS constraints could be on the order of milliseconds. In such applications it may become impractical or even impossible to satisfy the QOS constraints due to the mechanical latencies of the disk drives responsible for servicing the transaction data.

There is, therefore, a need to reduce the complexity and cost of implementing QOS constraints in a computer network, particularly with respect to the mechanical latencies of disk storage devices. In particular, there is a need to support QOS constraints on the order of milliseconds in transactions executed over a computer network.

SUMMARY OF THE INVENTION

The present invention may be regarded as a switched node comprising switching circuitry having more than two bi-directional ports for simultaneously transmitting data in multiple dimensions through the computer network, a disk for storing data, a head actuated over the disk for writing data to and reading data from the disk, and a reservation facility for reserving resources associated with data read from the disk and written to the disk to support a predetermined Quality-of-Service constraint with respect to data transmitted through the computer network.

In one embodiment, the resources reserved by the reservation facility comprise memory for buffering data within the switched node.

In another embodiment, the reservation facility limits movement of the head so as to constrain the head to a predetermined region of the disk, thereby reserving a resource within the

switched node.

In yet another embodiment, the switching circuitry comprises a plurality of virtual lanes and the resources comprise at least one of the virtual lanes.

The present invention may also be regarded as method of reserving resources in a computer network to support a predetermined Quality-of-Service constraint with respect to a new access request to transmit data between a disk drive and a client computer, the computer network comprising a plurality of interconnected computer devices including a plurality of disk drives, each disk drive comprising a head and a disk. The method comprises the steps of finding at least one disk drive out of the plurality of disk drives that can service the new access request while supporting the Quality-of-Service constraint for the new and existing access requests, and reserving resources within the at least one disk drive to service the new access request. The present invention may also be regarded as a computer network comprising a plurality of interconnected computer devices including a plurality of client computers and a plurality of disk drives for storing network data, each disk drive comprising a head and a disk. The computer network comprises a plurality of interconnected nodes, and a reservation facility for reserving resources within the disk drives and the nodes to support a predetermined Quality-of-Service constraint with respect to data transmitted between the disk drives and the client computers through the nodes of the computer network.

The present invention may also be regarded as a computer network comprising a plurality of interconnected computer devices including a plurality of disk drives for storing network data, each disk drive comprising a head and a disk. The computer network comprises a plurality of interconnected nodes, and a reservation facility for reserving resources within the disk drives and the nodes to support a predetermined Quality-of-Service constraint with respect to data transmitted between the disk drives through the nodes of the computer network.

The present invention may also be regarded as a switched fabric computer network comprising a plurality of interconnected nodes for simultaneously transmitting data in multiple dimensions through the computer network. Each node comprises switching circuitry comprising

more than two bi-directional ports, a disk for storing data, and a head actuated over the disk for writing data to and reading data from the disk. The switched fabric computer network further comprises a reservation facility for reserving resources associated with data read from the disk and written to the disk to support a predetermined Quality-of-Service constraint with respect to data transmitted between the interconnected nodes and client computers connected to the switched fabric computer network.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a prior art a computer network wherein a path is established between a client computer and a network server by reserving resources at each node to support a predetermined QOS constraint.

FIG. 2 shows details of the switched node according to an embodiment of the present invention comprising a disk, a head, and a reservation facility for reserving resources associated with the disk and head.

FIG. 3 shows a two dimensional switched fabric comprising a plurality of switched nodes, including switched nodes comprising a disk, a head, and switched nodes comprising adapter circuitry for connecting to an external entity.

FIG. 4 shows a switched fabric computer network according to an embodiment of the present invention wherein a path is established between a client and a disk drive by reserving resources in the switched nodes of a switched fabric as well as in the disk drive.

FIG. 5 shows a computer network according to an embodiment of the present invention wherein a path is established between a client computer and a disk drive connected to a network server by reserving resources at each node as well as within the disk drive to support a predetermined QOS constraint.

FIG. 6 shows a computer network according to an embodiment of the present invention wherein a path is established between a client computer and a network attached storage device (NASD) by reserving resources at each node as well as within the NASD to support a predetermined QOS constraint.

FIG. 7 shows details of a disk drive according to an embodiment of the present invention including a disk controller for reserving resources within the disk drive to support a predetermined QOS constraint.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 2 shows a switched node 14_i according to an embodiment of the present invention. The switched node 14_i comprises switching circuitry having more than two bi-directional ports for simultaneously transmitting data in multiple dimensions through the computer network, a disk 16a for storing data and a head 16b actuated over the disk 16a for writing data to and reading data from the disk 16a, and a reservation facility 18A-18E for reserving resources associated with data read from the disk 16a and written to the disk to support a predetermined Quality-of-Service constraint with respect to data transmitted through the computer network.

In contrast to the prior art techniques for supporting Point-to-Point QOS constraints by reserving resources at the nodes in a path between two entities in a network, the embodiment of FIG. 2 supports End-to-End QOS constraints by reserving resources at the end of the path (i.e., at the disk drive) as well as at the nodes through the path. In an embodiment described below, a path is established between two disk drives connected to the network and resources are reserved at both ends of the path (i.e., at both disk drives) as well as at the nodes in the path between the disk drives.

The switched node of FIG. 2 is interconnected with a plurality of other switched nodes 20 such as shown in FIG. 3 to form a multi-dimensional switched fabric. Each of the switched nodes in FIG. 3 comprises four bi-directional ports (North, East, South and West) forming a two-dimensional fabric. Control data 22 is generated by a switched fabric microprocessor, such as the microprocessor 24 in the switched fabric network 26 shown in FIG. 4. In one embodiment, the network data transmitted through the switched nodes 20 consist of packets having a packet header comprising routing data which identifies the source node for the packet. The packets are buffered in buffers 28_0-28_N, and the microprocessor 24 processes the packet header in order to route the packet through the switched nodes 20. A suitable routing algorithm implemented by

the microprocessor 24 of FIG. 4 generates control data 22 for configuring the switched nodes 20. Any suitable routing algorithm may be employed, and it may support Unicast, Multicast, or Broadcast delivery mechanisms. The routing decisions may be made centrally, at the source, distributed, or multiphase, implemented using a lookup table or using a finite-state machine. Further, the routing algorithm may be deterministic or adaptive. A discussion of various routing algorithms which may be employed in the embodiments of the present invention is provided by Jose Duato et al. in the textbook "Interconnection Networks, an Engineering Approach", IEEE Computer Society, 1997.

The routing algorithm is implemented a layer "above" the switching layer, and thus the routing algorithm may be compatible with various different switching algorithms, for example, Virtual Cut-Through Switching, Wormhole Switching, and Mad Postman Switching. In addition, topologies other than the two-dimensional switched fabric of FIG. 3, as well as topologies comprising more than two dimensions, may be employed in the present invention by decreasing or increasing the number of bi-directional ports per switched node. Various topologies and switching algorithms which may be employed in the embodiments of the present invention are discussed in the aforementioned textbook by Jose Duato et al.

In the embodiment shown in FIG. 3, the switched nodes 20 constituting the switched fabric suitably comprise processing circuitry and memory to facilitate the routing, scheduling and resource reservation operations. In addition, the switched nodes 20 may or may not comprise a disk 16a and a head 16b. Also in the embodiment of FIG. 3, a select number of the switched nodes 20 comprise adapter circuitry 21 for connecting to an external entity (e.g., a client computer in FIG. 4). In the example of FIG. 3, switched nodes 14_0-14_2 comprise a disk 16a and a head 16b as shown in FIG. 2, switched nodes 15_0-15_2 comprise the circuitry shown in FIG. 2 without the disk 16a and head 16b, and switched nodes 17_0-17_2 comprise adapter circuitry 21 for connecting to an external entity and may or may not comprise a disk 16a and a head 16b. In another embodiment, a selected number of the switched nodes (e.g., 15_0-15_2) comprise a microprocessor for implementing a distributed routing algorithm.

Referring again to FIG. 2, the bi-directional ports of the switched node 14_i comprise four input ports 30A-30D and four output ports 32A-32D corresponding to the North, East, South and West ports shown in FIG. 3. Data packets received from the input ports 30A-30D are buffered in FIFO buffers 34A-34D. A routing table 36 is configured by the control data 22 generated by the microprocessor 24 of FIG. 4. The routing table 36 generates control signals 38A-38D which configure multiplexers 40A-40D in order to route the data packets to appropriate data buffers 42A-42D associated with the output ports 32A-32D. In this manner, the data packets cross the switched node 14_i immediately except for the delay of the FIFO buffer 34A-34D. The FIFO buffers 34A-34D provide buffering of input data in the event that the target data buffer 42 is full or busy receiving data from another of the input ports.

The data packets may also be routed to an input port 44 associated with the disk 16a and the head 16b and stored in data buffer 46, wherein the data stored in data buffer 46 is ultimately written onto the disk 16a. Data read from the disk 16a is also stored in the data buffer 46 and transmitted via output port 48 to the appropriate data buffer 42A-42D.

A scheduling facility 50A-50E is also provided within the switched node 14_i which schedules the time when the data packets are to be transferred from the data buffers 42A-42D to the output ports 32A-32D, and when data packets are transferred to and from the disk 16a. In one embodiment, the timing information for the packets are stored in the packet headers and processed by the scheduling facility 50A-50E. In one embodiment, the timing information implements an isochronous communication protocol such as disclosed in the in Texas Instruments' TSB12LV41A link-layer controller (LLC) which supports the IEEE 1394 specification for high-performance serial bus with automatic generation of the common isochronous packet headers and time stamping as required by the IEC 61883 standard.

In one embodiment, the data buffers 42A-42D comprise a plurality of virtual lanes where each virtual lane is assigned a predetermined priority level. The scheduling facility 50A-50D schedules the data packets according to the timing information by queuing the data packets in the appropriate virtual lanes. For example, data packets with shorter transmission deadlines are

queued in higher priority virtual lanes, whereas data packets with longer transmission deadlines are queued in lower priority virtual lanes. In addition, within a virtual lane the data packets can be queued in order of arrival (FIFO) or in order of departure based on the transmission deadlines in order to support predetermined QOS constraints. Details of departure queuing are disclosed by Jennifer Rexford, et al. in "A Router Architecture for Real-Time Communication in Multicomputer Networks", *IEEE Transactions on Computers*, Vol. 47, No. 10, October 1998, which is incorporated herein by reference.

In the embodiment of FIG. 2, the reservation facility 18A-18D within the switched node 14_i reserves resources associated with the scheduling facility 50A-50D to support predetermined QOS constraints for data transmitted through the switch node 14_i, and reservation facility 18E reserves resources associated with the scheduling facility 50E to support predetermined QOS constraints for data transmitted to and from the disk 16a. The scheduling facility 50E also comprises additional resources for implementing the interface between the data buffer 46 and the disk 16a.

In one embodiment, the reservation facility 18A-18D reserves a virtual lane to support predetermined QOS constraints with respect to data transferred through the switched node 14_i. In another embodiment, the reservation facility 18A-18D reserves processing circuitry within the switched node 14_i for implementing the routing and scheduling operations. In yet another embodiment, the switched node 14_i comprises circuitry for linking the output ports 32A-32D to input ports 30A-30D of other switched nodes, the linking circuitry has limited bandwidth, and the reservation facility 18A-18D reserves at least part of the linking circuitry bandwidth to support predetermined QOS constraints. In still another embodiment, the reservation facility 18A-18D reserves at least part of the adapter circuitry 21 shown FIG. 3 to support predetermined QOS constraints.

In another embodiment, the reservation facility 18E reserves memory within the data buffer 46 to support writing a data stream to the disk 16a or to support reading a data stream from the disk 16a. In yet another embodiment, the reservation facility 18E limits movement of

the head 16b with respect to the disk 16a so as to constrain the head 16b to a predetermined region of the disk 16a, thereby reserving a resource within the switched node 14_i.

The switched node of 14_i of FIG. 2 can be extended to add additional dimensionality by duplicating the circuitry associated with each bi-directional port (input port 30, FIFO 34, MUX 40, output port 32, etc.). In one embodiment, the switched node 14_i is a commodity device which comprises a facility for dynamically configuring the bi-directional ports to support a desired switched fabric topology. Thus, a number of the input ports 30A-30D and/or a number of the output ports 32A-32D may be configured to connect to ports of other switched nodes, whereas the remaining ports may be left unconnected.

FIG. 5 shows a computer network 52 according to another embodiment of the present invention wherein a plurality of disk drives 54_0-54_N are employed by a network server 56 to implement a network storage system. In one embodiment, each disk drive 54_i stores a mirrored copy of network data such that the data can be retrieved by a client from any one of the disk drives 54_0-54_N. Each disk drive 54_i comprises a reservation facility for reserving resources within the disk drive 54_i to support predetermined QOS constraints. For example, when client 58B requests data stored in the network storage system, a path 60 is established by reserving appropriate resources in nodes 62A and 62B, in the network server 56, and finally in disk drive 54_0. If client 58D simultaneously requests access to data stored in the network storage system, a path 64 is established by reserving resources in nodes 62C and 62D, in the network server 56, and in a disk drive other than disk drive 54_0 (e.g., disk drive 54_2) since disk drive 54_0 may not have sufficient resources available to service the request for client 58D as well as the request for client 58B.

In one embodiment, the network server 56 sends a client's request to each of the disk drives 54_0-54_N looking for a disk drive with sufficient resources to service the request. For example, when the network server 56 receives the request from client 58D, it first sends the request to disk drive 54_0. Disk drive 54_0 transmits a message back to the network server 56 indicating that the request cannot be serviced due to the drive's resources having already been

reserved to support path 60 established for the access request from client 58B. The network server 56 then sends the request to disk drive 54_1 and ultimately to disk drive 54_2 which is able to service the request. In another embodiment, the network server 56 multicasts the request to the disk drives 54_0-54_N and then selects from the disk drives which can service the request.

FIG. 6 shows a computer network 66 according to another embodiment of the present invention wherein the disk drives 54_0-54_N of FIG. 5 are implemented as network attached storage devices (NASD) comprising network communication circuitry for connecting directly to the network rather than through a network server 56 as in FIG. 5. In FIG. 6, client 68B is accessing the network storage system through path 70 established by reserving resources in nodes 72A and 72B as well as in NASD disk drive 54_1. A simultaneous access request by client 68D is serviced through path 74 by reserving resources in nodes 72C and 72D as well as in NASD disk drive 54_N.

In one embodiment, the access requests from the clients are sent to each NASD disk drive 54_0-54_N until one is found that has sufficient resources to service the request. For example, if in FIG. 6 the request from client 68D was first sent to NASD disk drive 54_1, NASD disk drive 54_1 would transmit a message to node 72C indicating that it could not service the request due to the resources already reserved for client 68B. Node 72C would then send the request to NASD disk drive 54_N which would reply with a message indicating that it has sufficient resources to service the request.

In another embodiment, a path is reserved between two disk drives. For example, disk drive 54_0 connected to the network server 56 or connected directly to the network (NASD) may establish a path with another disk drive connected to the network (e.g., a disk drive connected to client computer 58A or another NASD drive connected directly to the network, such as NASD disk drive 54_1). Resources are reserved within both disk drives, thereby supporting End-to-End QOS constraints.

FIG. 7 shows a disk drive 54_i for communicating with a client computer or with another disk drive through a computer network, such as the computer network of FIG. 5 or FIG. 6. The

disk drive 54_i comprises a disk 76 for storing data, a head 78 actuated over the disk 76 for writing data to and reading data from the disk 76, and a disk controller 80 for controlling access to the disk 76, wherein the disk controller 80 comprises a reservation facility for reserving resources within the disk drive 54_i to support predetermined QOS constraints with respect to data transmitted between the disk drive 54_i and the client computer through the computer network.

In one embodiment, the resources reserved by the reservation facility comprise memory 82 for buffering data within the disk drive 54_i. For example, when transmitting a data stream from the client computer to the disk drive 54_i, data received via the disk drive's interface 84 is stored in the memory 82 before being written to the disk 76. The disk controller 80 reserves a sufficient amount of memory 82 to ensure that the data flowing from the interface 84 is not interrupted for a sustained period so as to guarantee a Quality-of-Service with respect to the data received from the client computer. In one embodiment, the disk drive 54_i reserves a sufficient amount of memory 82 to service the client's request as well as other requests in an interleaved manner. Thus, while the disk drive 54_i is servicing another request, data associated with the client's request is buffered in the memory 82.

The disk controller 80 evaluates a queue of access requests, as well as the current capacity for the memory 82, to determine whether the client's request can be serviced. If the client's request cannot be serviced, the disk drive 54_i transmits a message to this effect to an external entity (e.g., to a network server or to a node in a network). If the client's request can be serviced, then the disk drive 54_i begins to store the client's data in the reserved area of the memory 82. The disk controller 80 then reads the client's data from the memory 82, performs appropriate data formatting (e.g., error correction code (ECC) encoding), and then writes the formatted data to the disk 76 via a read/write channel 86. The read/write channel 86 is also employed to read data from the disk drive wherein the ECC coding is used to detect and correct errors induced by the recording process.

In another embodiment, the reservation facility within the disk controller 80 limits movement of the head 78 so as to constrain the head 78 to a predetermined region 88 of the disk

76, thereby reserving a resource within the disk drive 54_i. In one embodiment, the predetermined region 88 is defined by a predetermined number of concentric tracks recorded on the disk 76 and centered about a predetermined radial location. For example, if a client's data stream is to be written to a particular track, then the reservation facility may limit movement of the head 78 so as to prevent the head 78 from deviating excessively from the data stream's track. This limits the seek time to the data stream's track in order to satisfy the QOS constraints. In other words, if the disk drive 54_i is servicing another request, the seek time to return the head 78 to the data stream's track will always be within a known threshold which ensures that the QOS constraints are satisfied with respect to the client's request to write the data stream to the disk 76.

In one embodiment, the disk controller 80 comprises suitable servo control facilities for controlling a voice coil motor (VCM) 90 which actuates the head 78 over the disk 76. The disk controller 80 limits movement of the head 78 through the servo control facilities, that is, by evaluating client requests as well as pending requests and then controlling the VCM 90 so as to prevent the head 78 from deviating outside of the predetermined region 88.

Resources within the disk drive 54_i may also be reserved to facilitate client requests to read data from the disk 76. For example, the data rate of the disk drive 54_i for any particular data stream may depend on the amount of memory 82 reserved for that data stream, where the memory 82 requirement increases as the desired data rate increases. This may be due, for example, to the error correction capabilities of the disk controller 80. Thus, the disk controller 80 evaluates the desired data rate for a client's requests, together with pending requests, to determine whether the disk drive 54_i has sufficient resources to satisfy the request. If so, the disk controller 80 reserves a sufficient amount of memory 82 to service the request; otherwise, the disk drive 54_i notifies an external entity as to the inability to service the request.

Limiting the head 78 to a predetermined region on the disk 76 may also facilitate transferring a data stream from the disk 76 to a client computer while satisfying predetermined QOS constraints. Similar to a write operation, limiting movement of the head 78 limits the seek time to ensure that the head 78 can return to a particular data track within a known period. That

is, it ensures the disk controller 80 can return the head 78 to a particular data track after servicing a current access request.

In one embodiment, the resources reserved by the reservation facility include network communication circuitry within the disk drive 54_i for use in communicating with the computer network. For example, the disk drive 54_i of FIG. 7 may comprise network communication circuitry for implementing an isochronous protocol, wherein at least part of this circuitry is reserved when a path is established for a client request. Suitable circuitry for implementing an isochronous protocol is disclosed in Texas Instruments' TSB12LV41A link-layer controller (LLC) which supports the IEEE 1394 specification for high-performance serial bus with automatic generation of the common isochronous packet headers and time stamping as required by the IEC 61883 standard.

In one embodiment, the disk drive 54_i of FIG. 7 is attached to a switched fabric computer network 26 as illustrated in FIG. 4. In this embodiment, the reservation facility will reserve resources in a path through the switched nodes 20 as well as resources within the disk drive 54_i in order to support QOS constraints for a client computer attached to the switched fabric computer network 26. The disk drive 54_i as well as the client computer may be attached to the edge of the switched fabric computer network 26, or they may be attached to an internal switched node through adapter circuitry 21 as shown in FIG. 3.

WE CLAIM:

1. A switched node for use in a computer network comprising:

(a) switching circuitry comprising more than two bi-directional ports for simultaneously transmitting data in multiple dimensions through the computer network;

(b) a disk for storing data and a head actuated over the disk for writing data to and reading data from the disk; and

(c) a reservation facility for reserving resources associated with data read from the disk and written to the disk to support a predetermined Quality-of-Service constraint with respect to data transmitted through the computer network.

2. The switched node of claim 1, wherein the resources comprise memory for buffering data.

3. The switched node of claim 1, wherein the switching circuitry comprises a plurality of virtual lanes and the resources comprise at least one of the virtual lanes.

4. The switched node of claim 3, wherein each virtual lane comprises a predetermined priority level.

5. The switched node of claim 3, wherein data is queued within each virtual lane in order of arrival into the switched node.

6. The switched node of claim 3, wherein data is queued within each virtual lane with respect to transmission deadlines associated with the data.

7. The switched node of claim 1, wherein the switching circuitry comprises processing circuitry and the resources comprise at least part of the processing circuitry.

8. The switched node of claim 1, wherein:

(a) the switching circuitry comprises linking circuitry for linking to other switched nodes

in the computer network;

(b) the linking circuitry comprises a limited bandwidth; and

(c) the resources comprise at least part of the linking circuitry bandwidth.

9. The switched node of claim 1, wherein:

(a) the switching circuitry comprises adapter circuitry for connecting to an external entity; and

(b) the resources comprise at least part of the adapter circuitry.

10. The switched node of claim 1, wherein the reservation facility limits movement of the head so as to constrain the head to a predetermined region of the disk, thereby reserving a resource within the switched fabric storage node.

11. A method of reserving resources in a computer network to support a predetermined Quality-of-Service constraint with respect to a new access request to transmit data between a disk drive and a client computer, the computer network comprising a plurality of interconnected computer devices including a plurality of disk drives, each disk drive comprising a head and a disk, the method comprising the steps of:

(a) finding at least one disk drive out of the plurality of disk drives that can service the new access request while supporting the Quality-of-Service constraint for the new and existing access requests; and

(b) reserving resources within the at least one disk drive to service the new access request.

12. The method of reserving resources as recited in claim 11, wherein the resources comprise memory for buffering data.

13. The method of reserving resources as recited in claim 11, wherein the resources comprise network circuitry for communicating with the computer network.

14. The method of reserving resources as recited in claim 13, wherein:

(a) the network circuitry comprises multi-port switching circuitry for simultaneously transmitting data in multiple dimensions through the computer network; and

(b) the resources comprise a virtual lane within the multi-port switching circuitry.

15. The method of reserving resources as recited in claim 14, wherein each virtual lane comprises a predetermined priority level.

16. The method of reserving resources as recited in claim 14, wherein data is queued within each virtual lane in order of arrival into the switched node.

17. The method of reserving resources as recited in claim 14, wherein data is queued within each virtual lane with respect to transmission deadlines associated with the data.

18. The method of reserving resources as recited in claim 14, wherein the multi-port switching circuitry comprises processing circuitry and the resources comprise at least part of the processing circuitry.

19. The method of reserving resources as recited in claim 14, wherein:

(a) the multi-port switching circuitry comprises linking circuitry for linking nodes in the computer network;

(b) the linking circuitry comprises a limited bandwidth; and

(c) the resources comprise at least part of the linking circuitry bandwidth.

20. The method of reserving resources as recited in claim 14, wherein:

(a) the multi-port switching circuitry comprises adapter circuitry for connecting to an external entity; and

(b) the resources comprise at least part of the adapter circuitry.

21. The method of reserving resources as recited in claim 11, wherein the step of reserving resources comprises the step of limiting movement of the head so as to constrain the head to a predetermined region of the disk.

22. A computer network comprising:

(a) a plurality of interconnected computer devices including a plurality of client computers and a plurality of disk drives for storing network data, each disk drive comprising a head and a disk;

(b) a plurality of interconnected nodes; and

(c) a reservation facility for reserving resources within the disk drives and the nodes to support a predetermined Quality-of-Service constraint with respect to data transmitted between the disk drives and the client computers through the nodes of the computer network.

23. The computer network of claim 22, wherein the resources comprise memory for buffering data.

24. The computer network of claim 22, wherein the resources comprise network circuitry for communicating with the computer network.

25. The computer network of claim 24, wherein:

(a) the network circuitry comprises multi-port switching circuitry for simultaneously transmitting data in multiple dimensions through the computer network; and

(b) the resources comprise a virtual lane within the multi-port switching circuitry.

26. The computer network of claim 25, wherein data is queued within each virtual lane in order of arrival into the switched node.

27. The computer network of claim 25, wherein data is queued within each virtual lane with respect to transmission deadlines associated with the data.

28. The computer network of claim 25, wherein the multi-port switching circuitry comprises processing circuitry and the resources comprise at least part of the processing circuitry.

29. The computer network of claim 25, wherein:

(a) the multi-port switching circuitry comprises linking circuitry for linking the nodes in the computer network;

(b) the linking circuitry comprises a limited bandwidth; and

(c) the resources comprise at least part of the linking circuitry bandwidth.

30. The computer network of claim 25, wherein:

(c) the multi-port switching circuitry comprises adapter circuitry for connecting to an external entity; and

(d) the resources comprise at least part of the adapter circuitry.

31. The computer network of claim 22, wherein the reservation facility limits movement of the head so as to constrain the head to a predetermined region of the disk, thereby reserving a resource within the disk drive.

32. The computer network of claim 22, wherein each node comprises multi-port switching circuitry for simultaneously transmitting data in multiple dimensions through the computer network.

33. A computer network comprising:

(a) a plurality of interconnected computer devices including a plurality of disk drives for storing network data, the disk drives each comprising a head and a disk;

(b) a plurality of interconnected nodes; and

(c) a reservation facility for reserving resources within the disk drives and the nodes to support a predetermined Quality-of-Service constraint with respect to data transmitted between the disk drives through the nodes of the computer network.

34. A switched fabric computer network comprising:

(a) a plurality of interconnected nodes for simultaneously transmitting data in multiple dimensions through the computer network, each node comprising:

switching circuitry comprising more than two bi-directional ports;

a disk for storing data; and

a head actuated over the disk for writing data to and reading data from the disk;

(b) a reservation facility for reserving resources associated with data read from the disk and written to the disk to support a predetermined Quality-of-Service constraint with respect to data transmitted between the interconnected nodes and client computers connected to the switched fabric computer network; and

(c) a scheduling facility, responsive to the resources reserved by the reservation facility, for scheduling the transmission of data through the interconnected nodes to support the predetermined Quality-of-Service constraint.

35. The switched fabric computer network of claim 34, wherein the resources comprise memory for buffering data.

36. The switched fabric computer network of claim 34, wherein the resources comprise network circuitry for communicating with the switched fabric computer network.

37. The switched fabric computer network of claim 34, wherein:

(a) the switching circuitry comprises a plurality of virtual lanes; and

(b) the resources comprise at least one of the virtual lanes.

38. The switched fabric computer network of claim 37, wherein data is queued within each virtual lane in order of arrival into the switched node.

39. The switched fabric computer network of claim 37, wherein data is queued within each virtual lane with respect to transmission deadlines associated with the data.

40. The switched fabric computer network of claim 34, wherein the switching circuitry comprises processing circuitry and the resources comprise at least part of the processing circuitry.

41. The switched fabric computer network of claim 34, wherein:

(a) the switching circuitry comprises linking circuitry for linking to other switched nodes in the computer network;

(b) the linking circuitry comprises a limited bandwidth; and

(c) the resources comprise at least part of the linking circuitry bandwidth.

42. The switched fabric computer network of claim 34, wherein:

(e) the switching circuitry comprises adapter circuitry for connecting to an external entity; and

(f) the resources comprise at least part of the adapter circuitry.

43. The switched fabric computer network of claim 34, wherein the reservation facility limits movement of the head so as to constrain the head to a predetermined region of the disk, thereby reserving a resource within the node.

RESOURCE RESERVATION SYSTEM IN A COMPUTER NETWORK TO SUPPORT END-TO-END QUALITY-OF-SERVICE CONSTRAINTS

ABSTRACT OF THE DISCLOSURE

A computer network is disclosed comprising a plurality of interconnected computer devices including a plurality of disk drives for storing network data, each disk drive comprising a head and a disk. The computer network comprises a plurality of interconnected nodes, and a reservation facility for reserving resources within the disk drives and the nodes to support a predetermined Quality-of-Service constraint with respect to data transmitted between the disk drives through the nodes of the computer network. In one embodiment, a switched node is disclosed comprising switching circuitry having more than two bi-directional ports for simultaneously transmitting data in multiple dimensions through a computer network, a disk for storing data, a head actuated over the disk for writing data to and reading data from the disk, and a reservation facility for reserving resources associated with data read from the disk and written to the disk to support the predetermined Quality-of-Service constraint with respect to data transmitted through the computer network.

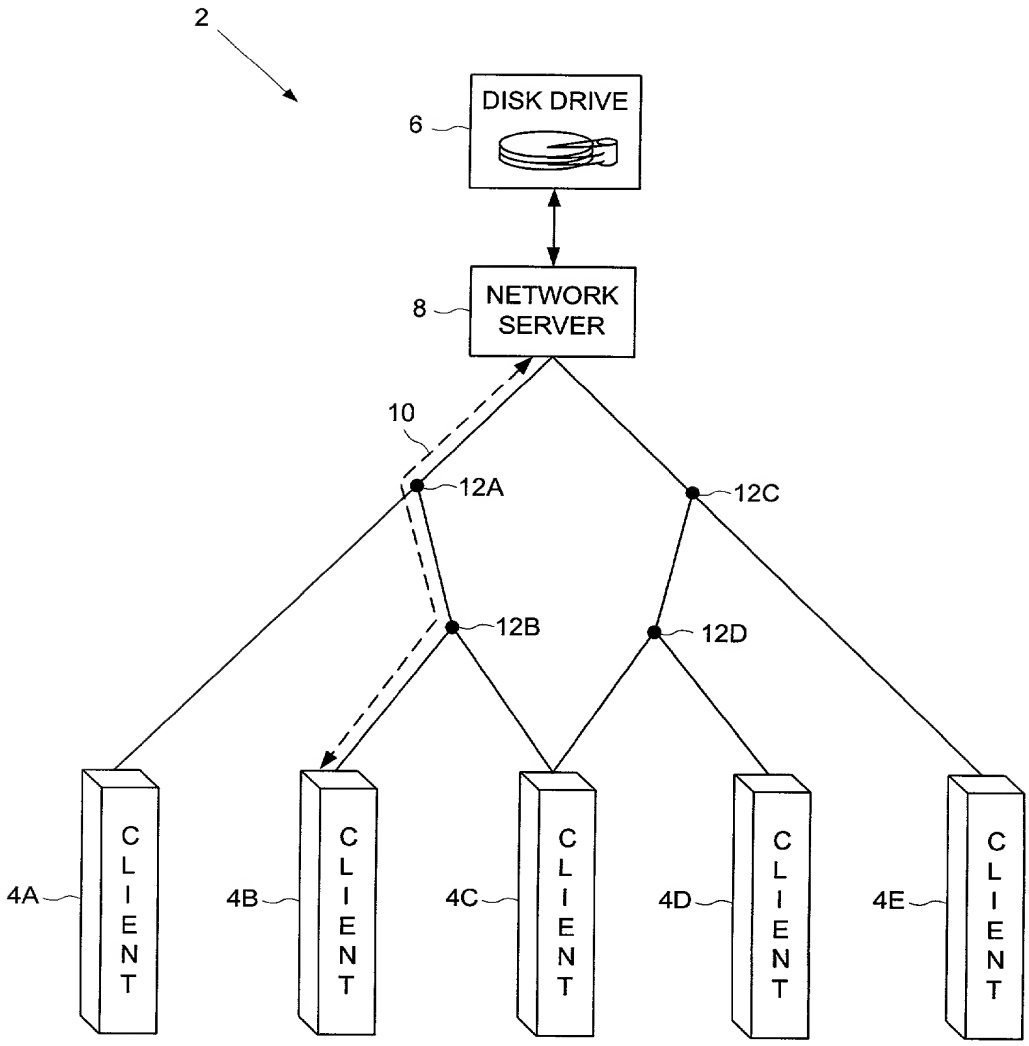


FIG. 1
(Prior Art)

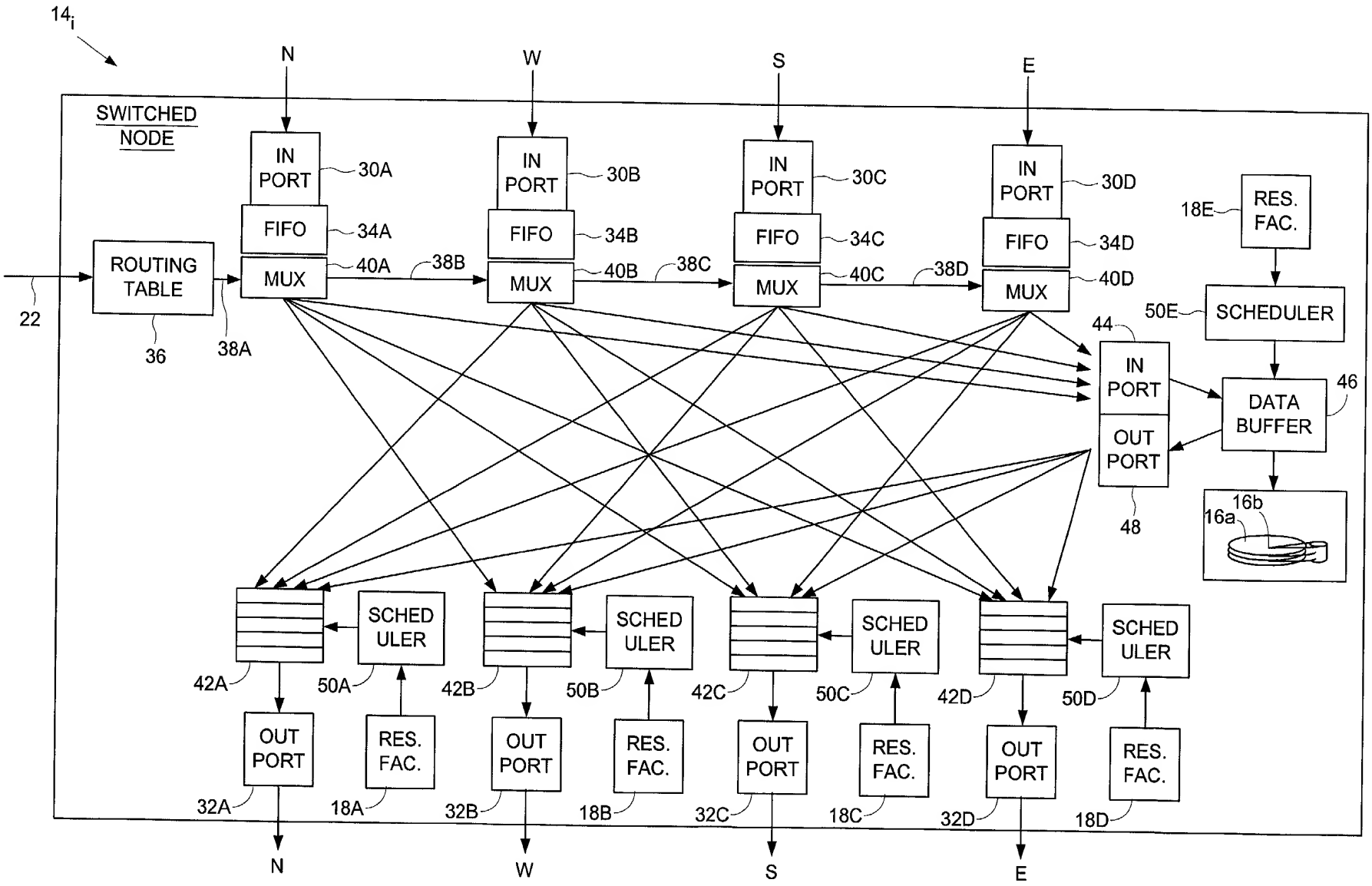
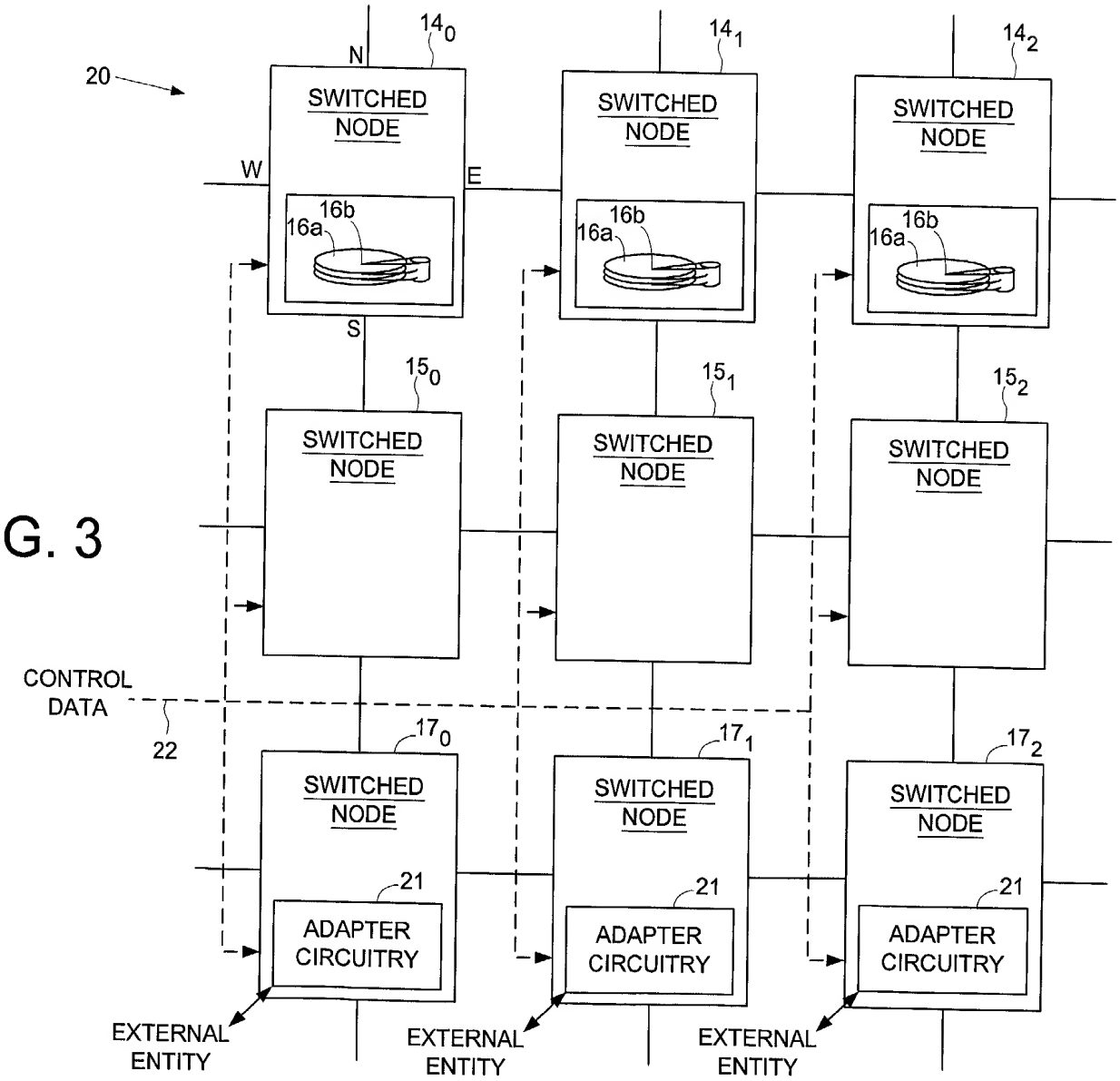


FIG. 2

FIG. 3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W
E
S
SWITCHED NODE
16a
16b
CONTROL DATA
22
ADAPTER CIRCUITRY
21
EXTERNAL ENTITY

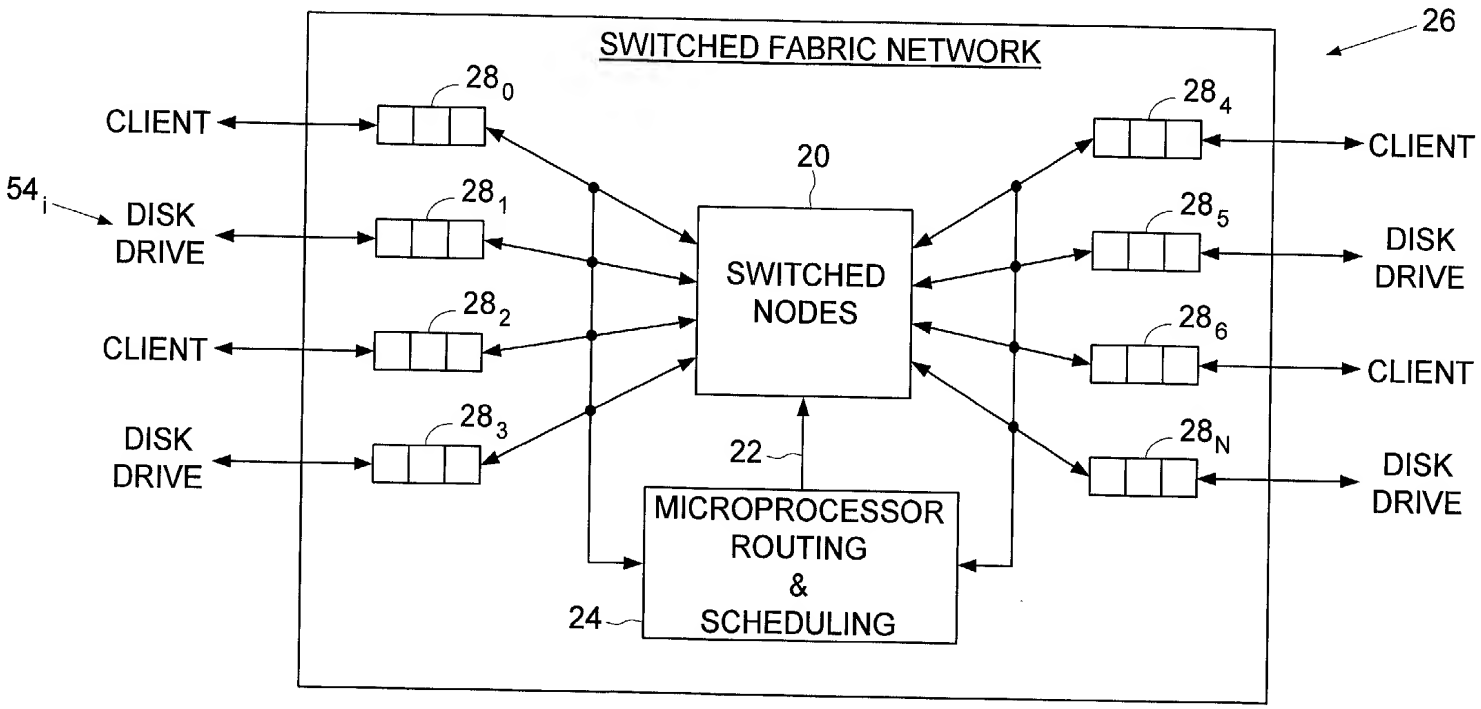
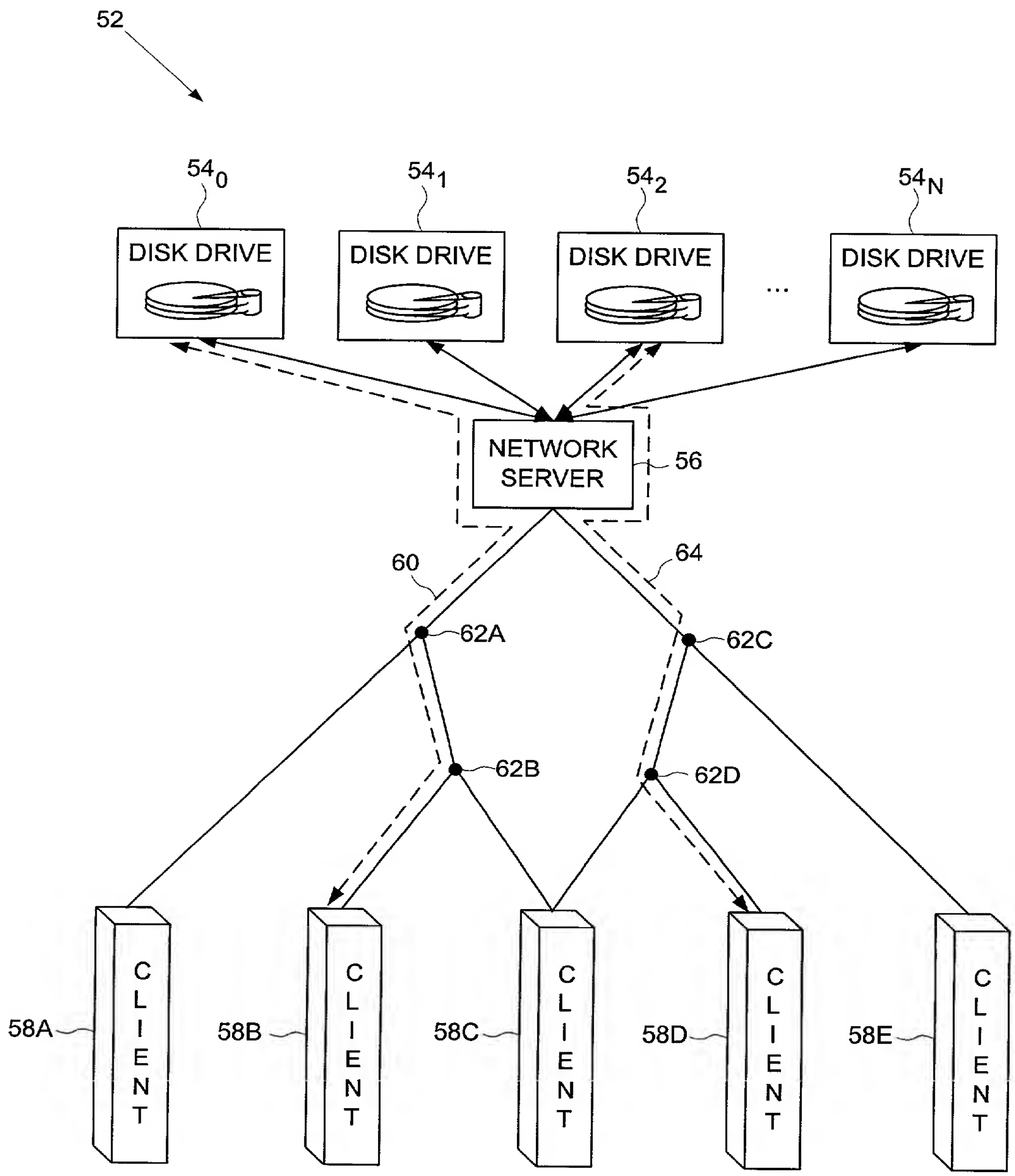
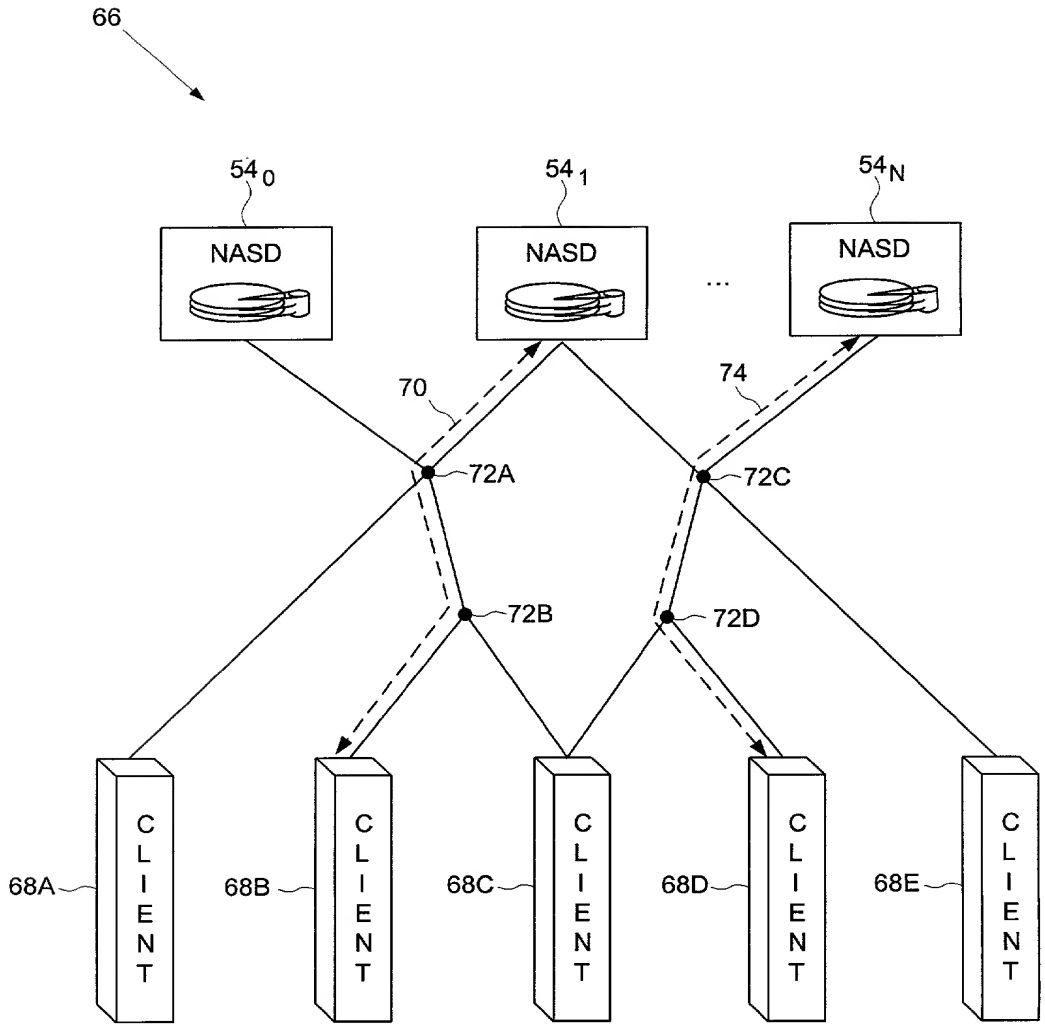

SWITCHED FABRIC NETWORK
26
20
SWITCHED NODES
22
MICROPROCESSOR ROUTING & SCHEDULING
24
28_0
28_1
28_2
28_3
28_4
28_5
28_6
28_N
CLIENT
54_i
DISK DRIVE
CLIENT
DISK DRIVE
CLIENT
DISK DRIVE
CLIENT
DISK DRIVE

FIG. 4



52
54_0
54_1
54_2
54_N
DISK DRIVE
DISK DRIVE
DISK DRIVE
...
DISK DRIVE
NETWORK SERVER
56
60
64
62A
62B
62C
62D
58A
58B
58C
58D
58E
CLIENT
CLIENT
CLIENT
CLIENT
CLIENT

FIG. 5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NASD
NASD
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70
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72C
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68D
68E
CLIENT
CLIENT
CLIENT
CLIENT
CLIENT

FIG. 6

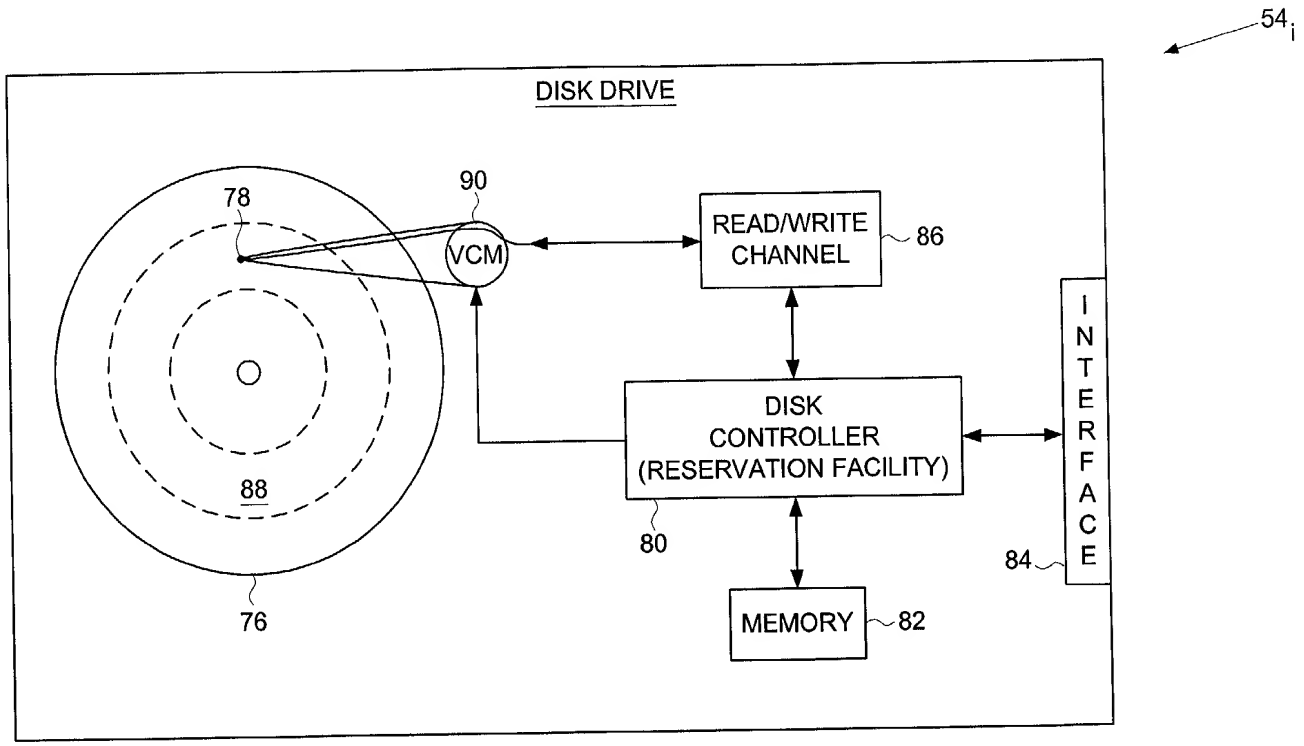
54i
DISK DRIVE
78
90
VCM
READ/WRITE CHANNEL
86
88
DISK CONTROLLER (RESERVATION FACILITY)
80
INTERFACE
84
MEMORY
82
76

FIG. 7

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☑ Declaration Submitted with Initial Filing **OR** ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	K35A0653
First Named Inventor	ANDREW D. HOSPODOR
COMPLETE IF KNOWN	
Application Number	/ Unknown
Filing Date	Herewith
Group Art Unit	Unknown
Examiner Name	Unknown

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

RESOURCE RESERVATION SYSTEM IN A COMPUTER NETWORK TO SUPPORT END-TO-END QUALITY-OF-SERVICE CONSTRAINTS

(Title of the Invention)

the specification of which
☑ is attached hereto
OR
☐ was filed on (MM/DD/YYYY) _____ as United States Application Number or PCT International Application Number _____ and was amended on (MM/DD/YYYY) _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1 56

I hereby claim foreign priority benefits under 35 U.S C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto

I hereby claim the benefit under 35 U S C 119(e) of any United States provisional application(s) listed below

Application Number(s)	Filing Date (MM/DD/YYYY)	
		☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U S C 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U S C 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1 56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number *(if applicable)*

☐ Additional U S or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith ☐ Customer Number [ ] → *Place Customer Number Bar Code Label here*
OR
☑ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Milad G. Shara	39,367		
Howard H. Sheerin	37,938		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto

Direct all correspondence to: ☐ Customer Number or Bar Code Label [ ] *OR* ☑ Correspondence address below

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Address	8105 Irvine Center Drive, Plaza 3						
City	Irvine			State	California	ZIP	92618
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U S C 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
ANDREW D.	HOSPODOR

Inventor's Signature	Andrew D. Hz					Date	9/21/00
Residence: City	LOS GATOS	State	CA	Country	USA	Citizenship	USA
Post Office Address	P.O. BOX 1196						
Post Office Address							
City	LOS GATOS	State	CA	ZIP	95031-1196	Country	USA

☑ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

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DECLARATION

ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 1 of 1

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])			Family Name or Surname				
MICHAEL K.			ENEBOE				
Inventor's Signature						9/24/98 **Date**	
Residence: City	SAN JOSE	**State** CA	**Country** USA			**Citizenship**	USA
Post Office Address	5379 RUCKER DR.						
Post Office Address							
City	SAN JOSE	**State** CA	**ZIP** 95124	**Country** USA			

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])			Family Name or Surname				
Inventor's Signature						**Date**	
Residence: City		**State** CA	**Country** USA			**Citizenship**	USA
Post Office Address							
Post Office Address							
City		**State** CA	**ZIP**	**Country** USA			

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])			Family Name or Surname				
Inventor's Signature						**Date**	
Residence: City		**State** CA	**Country** USA			**Citizenship**	USA
Post Office Address							
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